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SIMBOL-X, AN X-RAY TELESCOPE FOR THE 0.5–70 KEV RANGE

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Abstract. SIMBOL-X is a high energy “mini” satellite class mission that is proposed by a European collaboration for a launch in 2009. SIMBOL-X is making use of a classical X-ray mirror, of $\sim 600 \text{ cm}^2$ maximum effective area, with a 30 m focal length in order to cover energies up to several tens of keV. This focal length will be achieved through the use of two spacecrafts in a formation flying configuration. This will give to SIMBOL-X unprecedented spatial resolution ($20''$ HEW) and sensitivity in the hard X-ray range. By its coverage, from 0.5 to 70 keV, and sensitivity, SIMBOL-X will be an excellent instrument for the study of high energy processes in a large number of sources, both compact and extended.

1 Scientific motivation

The study of the non thermal component in high energy astrophysics sources is presently hampered by the large gap in spatial resolution and sensitivity between the X-ray and γ -ray domains. Below $\sim 10 \text{ keV}$, astrophysics missions like XMM-Newton and Chandra are using focusing optics based on grazing incidence mirrors giving extremely good spatial resolution, down to $0.5''$ for Chandra, and sensitivity. This technique has however an energy limitation at $\sim 10 \text{ keV}$ due to the maximum focal length that can fit in a single spacecraft. Hard X-ray and γ -ray imaging instruments, such as those on INTEGRAL, are relying on non focusing techniques which do not allow to reach spatial resolutions better than ~ 10 arc minutes and yield much lower point source sensitivities than in low energy X-rays.

This transition of techniques unfortunately happens roughly at the energy above which the identification of a non thermal component is unambiguous with respect to thermal emission. Considered from the low energy side, this strongly limits the interpretation of the high quality X-ray measurements, and particularly that related to the acceleration of particles. Considered from the high energy side, this often renders impossible the identification of the source of the γ -ray emission.

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The SIMBOL-X motivation is to elucidate the origin of the non thermal emission in accretion / acceleration astrophysical sites, both compact and extended, by offering a spatial resolution and a sensitivity of the “soft X-ray type” from 0.5 to up to ~ 70 keV. With SIMBOL-X it will be possible to solve issues or make new advances on the physics of the accretion onto black holes (both of stellar mass with new capabilities regarding low luminosity states, and much more massive as SgrA* or those in AGNs), on the high energy emission in jets both of quasars and micro-quasars, on the origin of the hot component at the centre of our Galaxy and in clusters of galaxies, on the particle acceleration in supernovae remnants, on magnetically active stars, or on the diffuse X-ray background in the energy range where its spectrum is peaking.

2 Mission concept

SIMBOL-X is built on the classical design of a Wolter I optics focusing X-rays onto a focal plane detector system. The gain in maximum energy is achieved by having a focal length of 30 metres, *i.e.* 4 times that of XMM-Newton mirrors. Since this cannot fit in a single spacecraft, the mirror and the detectors will be flown on two separate spacecrafts, in a formation flying configuration, as sketched in Fig. 1. We shortly detail below each part of this system.

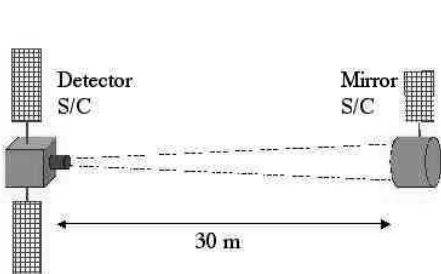


Fig. 1. SIMBOL-X two spacecrafts configuration.

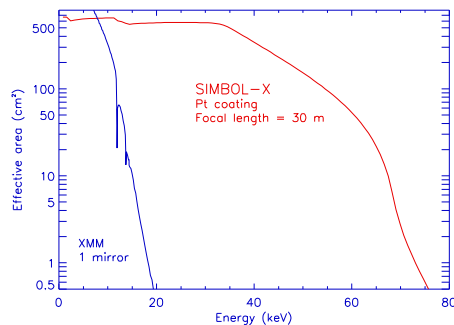


Fig. 2. Mirror effective area in the baseline configuration, compared to that of one XMM-Newton mirror.

The focusing optics will be a nested shells Wolter I configuration mirror. Building on the experience acquired on Beppo-SAX, Jet-X, SWIFT, ABRIXAS and XMM-Newton mirrors, it will be made following the Nickel electroforming replication method (*e.g.* Citterio *et al.* 2001). The current design is to have a 108 shells mirror, with an outer diameter of 70 cm (like one XMM-Newton module), and an angular resolution of 20 arcseconds of Half-Energy-Width. The coating will be Pt, in order to increase the high energy response w.r.t. a more classical Au coating. The focal length will be 30 metres.

Figure 2 shows the effective area as a function of energy, for the baseline design. It has roughly a constant value of 600 cm^2 up to about 35 keV, before starting to

decrease and fall below one cm^2 above more than 70 keV. The field of view will be of 6 arcminutes at 50 % vignetting.

The focal plane detector system will be a 6 cm diameter spectro-imager with $500\ \mu\text{m}$ of maximum pixel size (to provide an oversampling of the mirror PSF) with a “reasonable” spectral resolution below 10 keV for measuring lines, particularly that of Iron, and a 100 % efficiency at high energy. Since this cannot be given by a single detector, the focal plane will combine a low energy detector, stopping photons up to ~ 15 keV, directly on top of high energy detector. This is completed by an optical blocking filter, and an active anticoincidence shield. The best option for the low energy detector today is a DEPFET based APS (*e.g.* Holl 2002) which operates at room temperature, but thick depletion CCDs would also fit SIMBOL-X requirements. These detectors are currently under tests in the MPE Garching and Leicester University. The high energy detector will consist in 2 mm thick CdZnTe pixellated arrays (*e.g.* Limousin 2002) currently under tests in CEA/SAp.

Both mirror and detector spacecrafts will be of the “mini-satellite” class (500 kg max). To keep a constant image quality requires the following constraints on the spacecraft relative positionning : i) their distance must be kept constant within 1 cm, ii) their positionning perpendicular to the optical axis must be kept within 1 cm, and monitored with a 0.5 mm accuracy, and iii) the angular stability must be better than 1 arcmin, and monitored to 3 arcsec. In order to minimize the differential forces between the 2 spacecrafts, as well as to allow uninterrupted observations of variable sources, SIMBOL-X will be put in orbit around L2.

3 Sensitivity

Figure 3 presents the SIMBOL-X sensitivity to point sources, or equivalently to diffuse emission on a 1 arcmin diameter scale, compared to other instruments. SIMBOL-X curve was derived using the background spectrum of Ramsey (2001) for the HXT CdZnTe detector envisioned for Constellation X (also at L2 position), and a model of the astrophysical diffuse background. As expected for an X-ray focusing telescope, the SIMBOL-X sensitivity curve has roughly the shape of the XMM-Newton and Chandra curves (which have no diffuse background component here) but is displaced by about a decade in energy. SIMBOL-X is ~ 100 times better than existing instruments in the 10 to 35 keV range, and has a sensitivity equivalent to INTEGRAL/IBIS at ~ 70 keV.

We have also used this background model to simulate a number of observations that cannot be detailed here. We simply mention two examples to illustrate the SIMBOL-X sensitivity. On the supernovae remnant side, a detailed map of Cas A above 20 keV can be done in 100 ksec, and the spectrum of its brightest $1\ \text{arcmin}^2$ part is significant up to 50 keV. On the AGN jet side, the spectrum of the Pictor A hot spot at 4 arcmin from the nucleus (well isolated with SIMBOL-X optics) can be significantly measured up to 40 keV in 50 ks of observation.

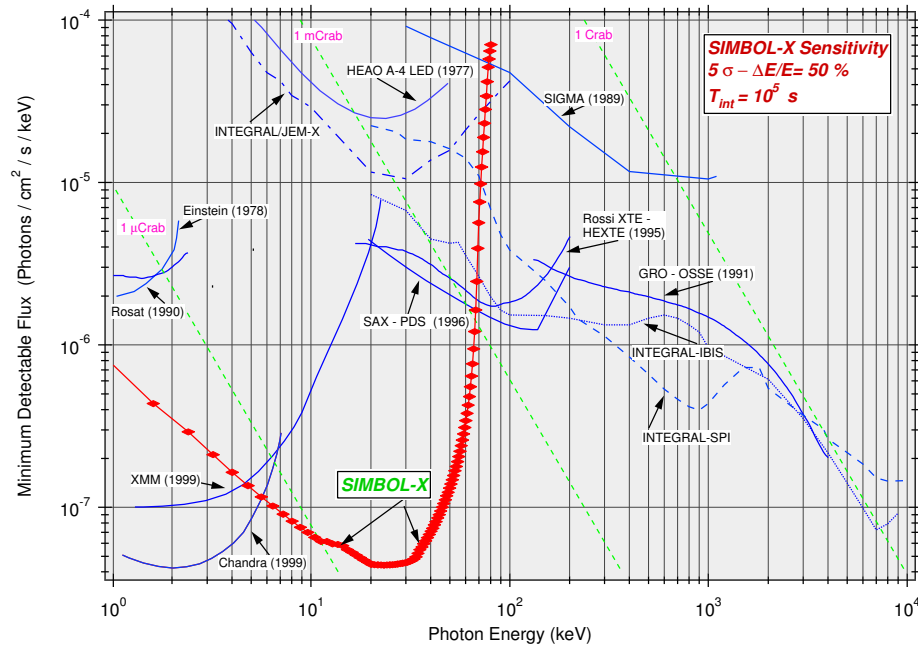


Fig. 3. SIMBOL-X sensitivity to point sources, compared to past and present X and γ -ray telescopes.

4 Collaboration and schedule

SIMBOL-X is a collaboration between France (CEA/Saclay, PI Institute, and the Grenoble and Meudon observatories), Italy with Brera Observatory, Germany with MPE Garching, and United Kingdom with Leicester University.

As SIMBOL-X does not involve new difficult technological development neither on the detector side nor on the mirror side, and as the formation flying constraints are rather well within current investigations in this domain, a relatively short development time can be envisioned. Launching SIMBOL-X before the end of the decade would provide an excellent scientific preparation to the much larger observatories Constellation X and XEUS that are scheduled later.

SIMBOL-X has been presented to the Astrophysics group of CNES, the french space agency, with a proposed launch date of early 2009. It has been recommended in June 2002 for a phase A study.

References

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